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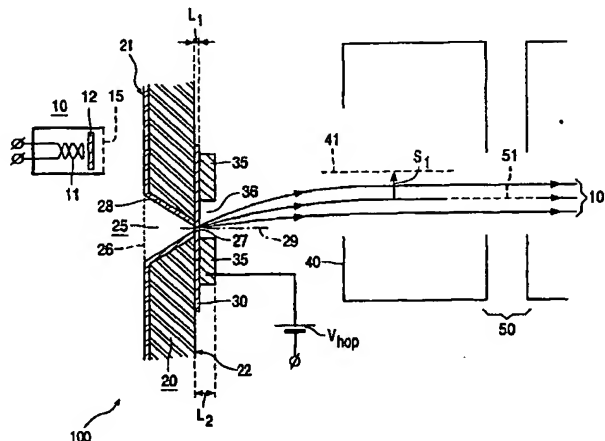
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(75) Inventors/Applicants (for US only): **VAN DER VAART, Nijs, C.** [NL/NL]; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **VAN DER POEL, Willibrordus, A., J., A.** For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **ELECTRON GUN, CATHODE RAY TUBE, AND PICTURE DISPLAY DEVICE**



(57) Abstract: The invention relates to an electron gun (100) for use in a cathode ray tube. The electron gun (100) has an electron source (10), a body (20) with a transmission cavity (25) of which the wall (28) is at least partly coated with an electrical insulator for the emission of secondary electrons, and an electrode (30) for applying a first electric field between the entrance (26) and the exit (27) of the cavity. The electron gun is characterized in that it comprises means for preventing the travelling of positive ions, which are formed by collisions of electrons that have exited from the cavity (25), in reverse direction along the same path as the electrons and colliding with the module (20). Such collisions can damage the cavity exit (27) or the electrical insulator on the wall (28). This is undesirable because the current density of the electron beam (101) exiting from the cavity (25) will deteriorate. This effect is prevented through the application of the deflection means according to the invention.

WO 02/097845 A2

Electron gun, cathode ray tube, and picture display device

The invention relates to an electron gun comprising:

an electron source for emitting electrons;

a module provided with a transmission cavity having an entrance, an exit, and
a wall which is formed at least in part from an electrically insulating material capable of
5 emitting at least a secondary electron after receipt of an electron incident on said material;

a hop electrode for applying a first electric field between the entrance and the
exit, which field during operation provides the transport of secondary electrons emitted by
the source from the entrance through the transmission cavity to the exit;

an accelerating grid for accelerating electrons issuing from the exit away from
10 said exit; and

a main lens for focusing the exited electrons.

Such an electron gun is known from the published international patent
15 application WO 00/79558. The known gun has a hop electrode for applying the first electric
field which causes the transport of electrons. This field is applied in longitudinal direction
across the transmission cavity. The required strength E_1 of the first electric field depends on
the geometry and dimensions of the wall of the transmission cavity as well as on a secondary
electron emission coefficient δ of the electrically insulating material, also referred to as
20 emitter material hereinafter. This coefficient δ represents the number of secondary electrons
which is emitted as a result of an electron incident on the emitter material in dependence on
an energy E_p of an electron incident on the wall. The strength of the electric field E_1 is
chosen such that one secondary electron is emitted for each electron impinging on the emitter
material, averaged over the entire transmission cavity, i.e. δ is equal to 1.

25 The same number of electrons will leave the transmission cavity through the
exit as entered it through the entrance in this case during operation. The transmission cavity
may act as an electron concentrator if the surface area of the exit is smaller than the surface
area of the entrance, for example by a factor 1000. The beam of emerging electrons will then
have a small cross-section and a high current density at the area of the exit opening then.

The electron gun may be used in a cathode ray tube. A system of electron lenses arranged therein images the exit opening on a screen which is provided with lines or dots of phosphors. The phosphor lights up wherever the electron beam hits the screen. The cathode ray tube comprises magnetic deflection means such that the electron beam can be deflected and the location of incidence of the electron beam on the screen can change. An image can be written onto the screen in this manner. The cathode ray tube may be used in a picture display device.

It is a problem of the known electron gun that the current density of the beam changes during the operational life of the electron gun. If the electron gun is used in a picture display device, this will result in a decreasing quality of the image of the exit opening on the screen. This image on the screen will be denoted the spot hereinafter.

It is an object of the invention to provide an electron gun of the kind mentioned in the opening paragraph in which the change in the current density of the electron beam during the operational life of the gun is counteracted.

According to the invention, this object is achieved in the electron gun in that deflection means are present for causing the exited electrons and ions released by the exited electrons to follow mutually differing paths.

The invention is based on the recognition that the change in the current density of the electron beam during use of the known gun is a result of positive ions formed by collisions of the exited electrons with gas molecules farther onward in the electron gun or in a cathode ray tube provided with the electron gun. The positive ions follow substantially the same path as the exiting electrons but in an opposite direction, i.e. towards the transmission cavity and the exit. Since the positive ions are accelerated between the accelerating grid and the exit, they will arrive at the module with a substantial kinetic energy and are then capable of damaging the module in at least two ways.

Firstly, the edge of the exit opening may be damaged in that ions colliding with the edge knock out material therefrom. The surface area of the exit opening, and accordingly the surface area of the beam of emerging electrons, is enlarged thereby. Since the beam current density is inversely proportional to the surface area of the beam, the beam current density becomes smaller. The size of the spot will now change in a cathode ray tube.

Secondly, the number of ions entering the transmission cavity through the exit is also reduced in the electron gun according to the invention. Ions entering the transmission

cavity may damage the emitter material. This material may accordingly become locally damaged after a certain time period during which the electron gun has been operating. This has the result that the secondary electron emission coefficient δ is locally changed, and incident electrons must have a higher energy level E_p in these locations if they are to emit a secondary electron. The electrons must be more strongly accelerated for this purpose, which requires a stronger electric field E_1 . In general, however, E_1 will not be corrected during product life, so that the number of exiting electrons may become smaller than the number of incoming electrons. The current density of the electron beam is reduced thereby.

The presence of the deflection means in the electron gun according to the invention strongly reduces the number of ions that return to the module adjacent the exit. Since the positive ions follow a path which is different from the path of the exiting electrons, they will in general no longer return to the module adjacent the exit. This means that fewer collisions take place between ions and the edge of the exit opening, so that this edge will become damaged less quickly. Fewer ions will also enter the transmission cavity, whereby damage to the emitter material of the wall of the transmission cavity is counteracted.

An electron gun with deflection means for ensuring that positive ions returning to the source cannot follow the path of the emitted electrons is known per se, for example from European patent EP 0795188. In a conventional electron gun, however, a thermionic cathode for the emission of electrons is protected, whereas it is the module which is protected in the electron gun according to the invention.

In an embodiment of the electron gun according to the invention, the deflection means comprise a deflection electrode for applying a deflecting electric field to the exited electrons. Applying a deflecting electric field by means of an electrode constitutes a simple and inexpensive manner in which to cause the ions and electrons to follow mutually differing paths. Alternatively, the deflection means may consist of a magnetic field for separating electrons and ions.

In the electron gun according to the invention, the hop electrode may be positioned adjacent the exit and may be provided with an opening for allowing electrons issuing from the exit to pass. The hop electrode receives a voltage V_{hop} during operation for the purpose of applying the first electric field E_1 . The placement of the hop electrode comparatively close to the module offers the advantage that this voltage may be comparatively low. The opening in the hop electrode may be circular, which shape is suitable for being imaged on the screen in a cathode ray tube.

The deflection electrode may be symmetrical in four quadrants and be provided with an opening. It may be placed adjacent the hop electrode so as to be eccentric with respect to the exit opening. Since the exit opening is not in the center of a four-quadrant symmetrical opening, the issuing electrons are subject to a deflecting electric field. The placement of the deflection electrode adjacent the hop electrode and the exit opening is effective because the electrons still have a comparatively low velocity here and as a result are still comparatively strongly deflected by the deflecting electric field. The accelerated ions have a comparatively high velocity adjacent the exit opening and accordingly are subject to a comparatively small deflection caused by the deflecting electric field. The accelerated ions cannot follow the paths of the deflected electrons adjacent the exit and shoot substantially straight through.

The deflection electrode may be positioned behind the hop electrode along the electron-optical main axis of the main lens, as viewed from the module. The opening in the deflection electrode then has a diameter which is greater than a greatest cross-section of the exit opening. An advantage of such a position of the deflection electrode is that the latter may as the same time serve as a so-called cup lens for prefocusing the electron beam. The diameter of the opening is greater than the greatest cross-section of the exit opening so as to prevent the electron beam from hitting against the deflection electrode.

Alternatively, the deflection electrode may be positioned substantially in the same plane as the hop electrode, such that the hop electrode lies within the deflection electrode. The deflection electrode again has the added object of prefocusing the electron beam in this configuration. This embodiment affords a wider freedom in the choice of the degree of prefocusing by the deflection electrode. Both configurations of the deflection electrode and the hop electrode are described in the published international patent application WO 01/26131.

Furthermore, the deflection electrode may comprise a first and a second segment which are arranged so as to be electrically insulated, the first segment being coupled to a first voltage source for receiving a voltage V_{a1} , and the second segment being coupled to a second voltage source for receiving a voltage V_{a2} , the voltage V_{a1} being greater than the voltage V_{a2} . The electric field caused by the various voltages between the segments acts as a deflecting electric field on the electron beam.

In an alternative embodiment of the electron gun according to the invention, the transmission cavity is symmetrical around a central axis adjacent the exit. The transmission cavity may then have a frustoconical shape adjacent the exit, a comparatively

small end face of said cone being the exit opening. A transmission cavity with such a shape acts as an electron concentrator when the electron gun is in operation. The circular exit opening causes a circular or elliptical spot upon imaging on a screen. The transmission cavity may in its entirety have a frustoconical shape of which the comparatively large initial surface is the entrance opening.

Alternatively, the transmission cavity may have a truncated pyramid shape adjacent the exit opening, a comparatively small end surface thereof being the exit opening. This shape, too, acts as an electron concentrator during operation. Imaging of the exit opening on a picture screen gives a rectangular spot. The transmission cavity may have a truncated pyramid shape in its entirety, the comparatively large initial surface being the entrance opening.

If the transmission cavity has a central axis, the latter may enclose an angle with an electron-optical main axis of the accelerating grid. This constitutes an alternative embodiment of the deflection means. The beam of exited electrons is substantially parallel to the central axis which encloses an angle with the electron-optical main axis of the accelerating grid. As a result of this, the accelerating grid deflects the exited electrons.

A main lens for focusing the electrons will generally be present in the electron gun. The electron-optical main axis of the accelerating grid may be eccentric with respect to the electron-optical main axis of the main lens so as to cause the path of the deflected electrons to coincide with an electron-optical main axis of the main lens. This has the advantage that the size and shape of the spot are optimized, because lens errors during focusing of the electrons, such as coma and convergence errors, are largely avoided.

These and other aspects of the electron gun according to the invention will be explained in more detail below with reference to the drawing(s), in which:

Fig. 1 is a cross-sectional view of a first embodiment of an electron gun according to the invention,

Fig. 2 is a front elevation of an electrode configuration in the first embodiment of the electron gun,

Fig. 3 is a cross-sectional view of an alternative embodiment of the module,

Fig. 4 is a front elevation of a first electrode configuration in the alternative embodiment of the module,

Fig. 5 is a front elevation of a second electrode configuration in the alternative embodiment of the module,

Fig. 6 is a cross-sectional view of a further embodiment of the module,

Fig. 7 shows a second embodiment of the electron gun according to the invention, and

Fig. 8 shows a color picture display device with a cathode ray tube provided with an electron gun according to the invention.

The electron gun 100 in Fig. 1 comprises an electron source 10, a module 20 provided with a transmission cavity 25, means 30 for applying a first electric field, and an accelerating grid 40.

The electron source 10 in the Figure is a thermionic cathode, electrons being emitted during operation through heating of a cathode 12 by an incandescent wire 11. A second electrode 15 is placed between the electron source 10 and the module 20 for applying a second electric field with a strength E_2 . This second electric field pulls released electrons away from the electron source 10. The beam current density is modulated in that the strength E_2 of the second electric field is changed.

The module 20 is provided with a transmission cavity 25 with an entrance 26 and an exit 27. In a first embodiment, the module 20 has a transmission cavity 25 with a frustoconical shape which is symmetrical around a central axis 29. At least a portion of the wall 28 of the transmission cavity 25 adjacent the exit 27 consists of an emitter material with an electron emission coefficient δ for emitting the secondary electrons. It is advantageous if the emitter material has a comparatively high δ , so that the strength of the first electric field E_1 can remain limited. The emitter material comprises, for example, magnesium oxide (MgO) and may have a layer thickness of 0.5 micrometer. Alternatively, the emitter material may comprise glass, polyamide, yttrium oxide (Y_2O_3) or silicon nitride (Si_3N_4). Part of a surface 21 of the module 20 laterally of the entrance opening 26 may also be provided with the emitter material. This has the advantage that emitted electrons hitting the surface 21 next to the entrance 26 release secondary electrons which subsequently drop into the entrance opening 26. As a result of this, the electron source 10 may be positioned eccentrically with respect to the transmission cavity 25 and accordingly with respect to the exit opening 27, as is shown in Fig. 1.

The emitted electrons enter the transmission cavity 25 through the entrance 26. The entrance 26 is indicated with a broken line in the drawing. Electron transport takes place under the influence of the first electric field E1 during operation, one electron leaving the exit 27 for each electron which enters the transmission cavity 25. In general, the exiting electrons are secondary electrons emitted by the emitter material after an electron has landed thereon. The emergence of electrons emitted by the source 10 without interaction with the emitter material is limited in this gun in that the electron source 10 and the exit opening 27 are eccentrically positioned. This offers an advantage, because electrons issuing without interaction with the emitter material have a too high energy and detract from the quality of the spot in a cathode ray tube.

The module 20 may be made from aluminum oxide (Al_2O_3), in which the transmission cavity is provided by means of a laser process or a mechanical process. The comparatively large initial surface of the frustoconical transmission cavity 25 forms the entrance opening 26. This is a circular opening with a diameter of, for example, 2.5 mm. The comparatively small end face of the frustoconical transmission cavity 25 forms the exit 27, which is a circular opening with a diameter of, for example, 40 micrometers. The angle enclosed between the wall 28 and the central axis 29 will generally lie between 30 and 60°, for example 35°.

The hop electrode 30 and the deflection electrode 35 are situated adjacent the exit 27. The hop electrode 30 may consist of a metal layer vapor-deposited on the surface 22 of the module 20, which layer is provided with an opening 31 adjacent the exit 27. Said metal layer comprises, for example, chromium and aluminum and has a thickness L1 of, for example, 2.5 micrometers. This metal layer may in addition comprise materials such as tungsten or titanium which are sputtered off comparatively slowly by ion bombardments, so as to reduce damage to the hop electrode 30. The opening 31 has a diameter D1 comparable to that of the exit 27, 40 micrometers in this example. The hop electrode 30 is coupled to a voltage source Vhop for applying the electric field E1 during operation. The value of E1 is chosen such that the electron transport through the transmission cavity 25 is possible, for which purpose Vhop is, for example, 1000 volts.

The deflection electrode 35 with an opening 36 therein is placed adjacent the hop electrode 30 such that this hop electrode lies between the module 20 and the deflection electrode 35. Furthermore, the hop electrode 30 and the deflection electrode 35 are interconnected. Alternatively, they may be separated by an insulator.

The deflection electrode 35 is symmetrical in four quadrants, for example circularly as shown in Fig. 2, and is provided with an opening 36 with a diameter D2. The deflection electrode 35 at the same time serves to prefocus the issuing electrons. The deflection electrode 35 has a thickness L2, for example of 250 micrometers. The opening 36 has a diameter D2, for example of 600 micrometers. It was found that, given a ratio $L2/D2$ of between 0.35 and 0.45, the deflection electrode 35 prefocuses the issuing electrons such that a beam 101 of the exited electrons optimally fills the main lens 50.

The eccentric placement of the deflection electrode 35 with respect to the exit opening 27 causes the electric field generated by the deflection electrode 35 to deflect the issuing electrons. The exit opening 27 is at a distance S2 from the center of the deflection electrode 35, for example 120 micrometers. This reduces an ion density adjacent the exit opening 27 by a factor ten during operation.

Owing to its deflection, the electron beam 101 encloses an angle both with the central axis 29 of the transmission cavity 25 and with an electron-optical main axis 51 of the main lens 50. The latter is undesirable, because it causes lens errors, such as convergence errors and coma, during focusing of the deflected electrons. This changes the sharpness of the spot in a cathode ray tube. To counteract this effect, the electron-optical main axis 41 of the accelerating grid 40 is shifted laterally over a distance S1 with respect to the main axis 51 of the focusing lens 50. As a result of this, the electron beam is parallel to the main axis 51 at the area of the focusing lens 50. The distance S1 is, for example, 200 micrometers.

In an alternative embodiment of the module 120, the hop electrode 130 and the deflection electrode 135 lie substantially in one and the same plane, as is shown in Fig. 3. The hop electrode 130 and the deflection electrode 135 both have a thickness L1 of, for example, 2.5 micrometers. A possible electrode configuration is shown in front elevation in Fig. 4. The deflection electrode 135 is annular in shape, with a diameter D3 of the opening 136 of, for example, 225 micrometers. The hop electrode 130 is circular with a diameter of, for example, 200 micrometers and lies within the deflection electrode 135. The hop electrode 130 has an opening 131 at the area of the exit 27. The diameter D1 of the opening 131 is comparable to that of the exit opening 27, i.e. 40 micrometers in this case. Such an electrode configuration may be manufactured in a manner analogous to that for the hop electrode 30 in the first embodiment, but in this case a larger portion of the surface 22 is covered with metal. Then the desired electrode configuration is obtained through removal of part of the metal layer, for example by means of etching.

The electric field of the deflection electrode 135 deflects the electron beam 101 and focuses it such that the main lens 50 is optimally filled. The deflection electrode 135 is coupled to a voltage source for receiving a voltage V_a , for example having a value of 600 volts, so as to generate this electric field. In a second electrode configuration, the deflection electrode 235 is subdivided into a first arc segment 235A and a second arc segment 235B, see Fig. 5. The arc segments 235A, 235B are separated by an electrical insulator. The deflecting electric field may be applied during operation in that a voltage V_{a1} is applied to the first arc segment 235A and a voltage V_{a2} is applied to the second arc segment 235B, V_{a1} being greater than V_{a2} . V_{a1} is, for example, 590 volts, and V_{a2} is, for example, 610 volts. The deflecting electric field is then present between the segments 235A and 235B, transverse to the electron beam 101 of the issuing electrons. The electron beam 101 is deflected thereby. The exit opening 27 of the transmission cavity 25 may be positioned centrally with respect to the opening 236 in this configuration.

A further embodiment of the module 320, shown in Fig. 6, has a transmission cavity 325 with a truncated pyramid shape, with a square entrance 326 and a square exit 327. Such a module 320 is manufactured, for example, through etching of a body consisting of silicon by means of potassium hydroxide (KOH). The angle enclosed by the wall 328 and the central axis 329 of the transmission cavity 325 then is, for example, 55° . The hop electrode 330 and the deflection electrode 335 are present adjacent the surface 322 of the module 320 around the exit opening 327.

A second embodiment of the electron gun 100 is shown in Fig. 7. The module 20 in this electron gun 100 is positioned obliquely in the electron gun 100, such that the central axis 29 of the transmission cavity 25 encloses an angle with the electron-optical main axis 41 of the accelerating grid 40. In this embodiment, the accelerating grid 40 comprises the deflection means, and the electrons exiting at an angle are subject to a deflecting electric field generated by the accelerating grid 40.

A color picture display device with a cathode ray tube K may be provided with an in-line electron gun 100 with three electron sources 10R, 10G, 10B for the colors red, green, and blue. Fig. 8 is a cross-sectional view of an electron gun 100' taken on the in-line plane. The electron gun 100' has a module 20 in which a transmission cavity 25R, 25G, 25B is separately provided for each color. The beams 101R, 101G, 101B of issuing electrons coming from the exit openings 27R, 27G, 27B are deflected by deflection electrodes 35R, 35G, 35B, respectively. The deflection preferably takes place in a direction perpendicular to the in-line plane. After issuing from the exit openings 27R, 27G, 27B, the exited electrons are

accelerated by an accelerating grid 40 and focused by a main lens 50. Deflection means 60 are provided in the cathode ray tube so as to have a possibility of changing respective spots of incidence of the electron beams 101R, 101G, 101B on a screen 70. Dots or lines of red, green, and blue phosphors are provided in alternation on the screen, which phosphors will
5 light up when hit by the respective electron beams 101R, 101G, 101B.

Besides a cathode ray tube K, a control unit A is also present for controlling the cathode ray tube K in a picture screen device. The control unit receives a video signal and supplies each electron source 10R, 10G, 10B with a separate modulation signal. The control unit A also supplies a control signal for the deflection means 60.

10 The drawings show a few embodiments of the invention. The drawings are diagrammatic and not true to scale. The embodiments depicted are merely meant to illustrate the invention and do not constitute any limitation thereof whatsoever.

CLAIMS:

1. A electron gun comprising:
an electron source (10) for emitting electrons;
a module (20) provided with a transmission cavity (25) having an entrance (26), an exit (27), and a wall (28) which is formed at least in part from an electrically
5 insulating material capable of emitting at least a secondary electron after receipt of an electron incident on said material;
a hop electrode (30) for applying a first electric field between the entrance (26) and the exit (27), which field during operation provides the transport of secondary electrons emitted by the source (10) from the entrance (26) through the transmission cavity (25) to the
10 exit (27);
an accelerating grid (40) for accelerating electrons issuing from the exit (27) away from said exit (27); and
a main lens (50) for focusing the exited electrons,
characterized in that deflection means (35; 40) are present for causing the exited electrons
15 and ions released by the exited electrons to follow mutually differing paths.
2. An electron gun as claimed in claim 1, characterized in that the deflection means comprise a deflection electrode (35) for applying a deflecting electric field to the
20 exited electrons.
3. An electron gun as claimed in claim 2, characterized in that the hop electrode (30) is positioned adjacent the exit (27) and is provided with an opening (31) for allowing electrons issuing from the exit (27) to pass.
- 25 4. An electron gun as claimed in claim 3, characterized in that the hop electrode is provided with a circular opening (31).
5. An electron gun as claimed in claim 3, characterized in that the deflection electrode (35) is symmetrical in four quadrants and is provided with an opening (36), and in

that the deflection electrode (35) is positioned adjacent the hop electrode (30) so as to be eccentric with respect to the exit opening (27).

6. An electron gun as claimed in claim 5, characterized in that the deflection electrode (35) is situated behind the hop electrode (30) along an electron-optical main axis (51) of the main lens (50), as viewed from the module (20), and in that a diameter of the opening (36) in the deflection electrode (35) is greater than a greatest diameter of the exit opening (27).
- 10 7. An electron gun as claimed in claim 3, characterized in that the deflection electrode (235A, 235B) comprises a first (235A) and a second (235B) segment, which segments are electrically insulated from one another, the first segment (235A) being coupled to a first voltage source for receiving a voltage Va1, and the second segment (235B) being coupled to a second voltage source for receiving a voltage Va2, the voltage Va1 being greater than the voltage Va2.
- 15 8. An electron gun as claimed in claim 5 or 7, characterized in that the deflection electrode (135; 235A, 235B) and the hop electrode (130; 230) are situated substantially in one and the same plane, and in that the hop electrode (130; 230) lies within the deflection electrode (135; 235A, 235B).
- 20 9. An electron gun as claimed in claim 1, characterized in that the transmission cavity (25) is symmetrical around a central axis (29) adjacent the exit opening (27).
- 25 10. An electron gun as claimed in claim 9, characterized in that the transmission cavity (25) has a frustoconical shape adjacent the exit opening (27), a comparatively small end face of said shape being the exit opening (27).
11. An electron gun as claimed in claim 9, characterized in that the transmission cavity (25) has a truncated pyramid shape adjacent the exit opening (27), a comparatively small end face of said shape being the exit opening (27).
- 30 12. An electron gun as claimed in claim 9, characterized in that the central axis (29) is at an angle to an electron-optical main axis (41) of the accelerating grid (40).

13. An electron gun as claimed in claim 1, characterized in that the electron-optical main axis (41) of the accelerating grid (40) is eccentric with respect to the electron-optical axis (51) of the main lens (50) so as to cause the path of the exited electrons to coincide with the electron-optical axis (51) of the main lens (50).
14. A cathode ray tube (K) provided with an electron gun as claimed in any one of the claims 1 to 13.
- 10 15. A picture display device provided with a cathode ray tube (K) as claimed in claim 14.

1/4

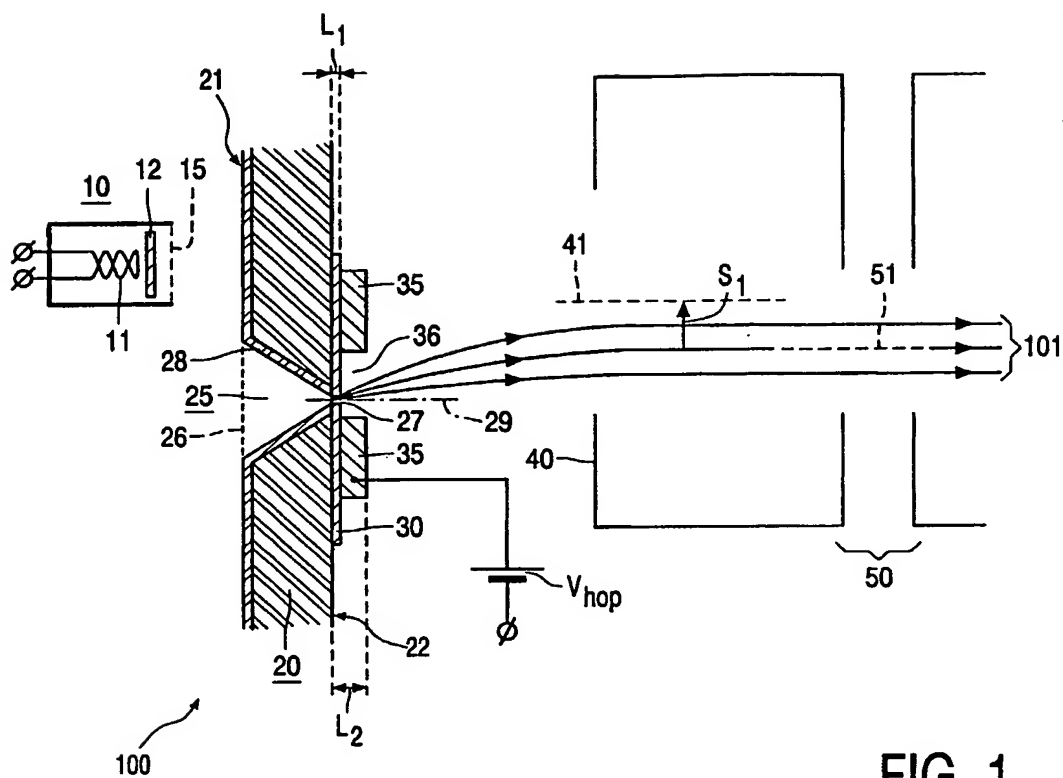


FIG. 1

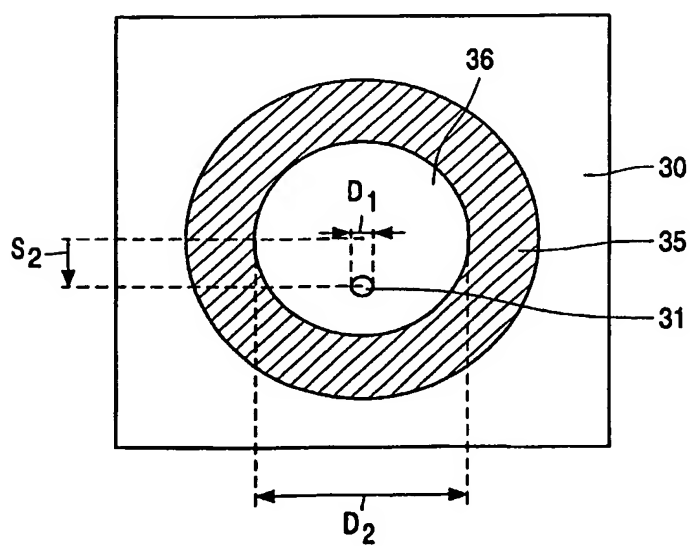


FIG. 2

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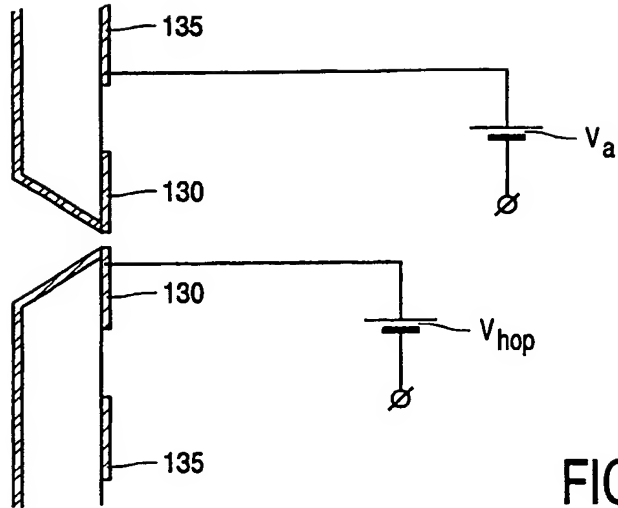


FIG. 3

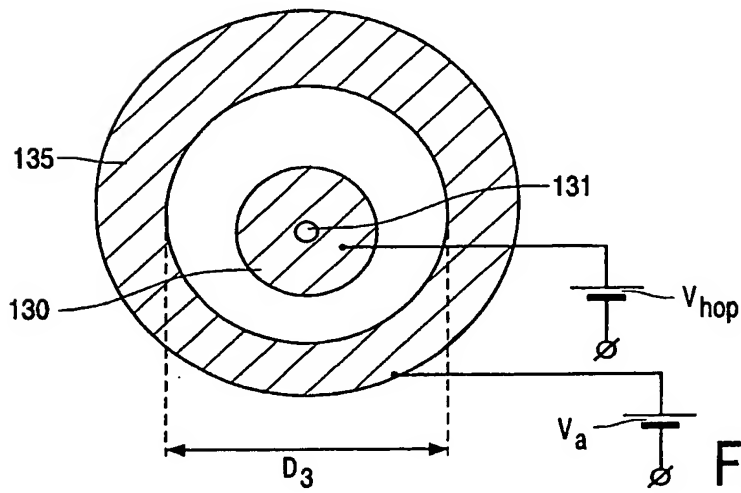


FIG. 4

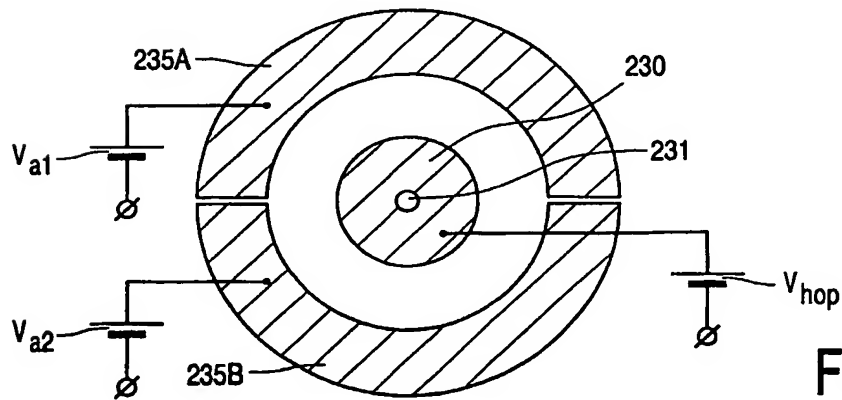


FIG. 5

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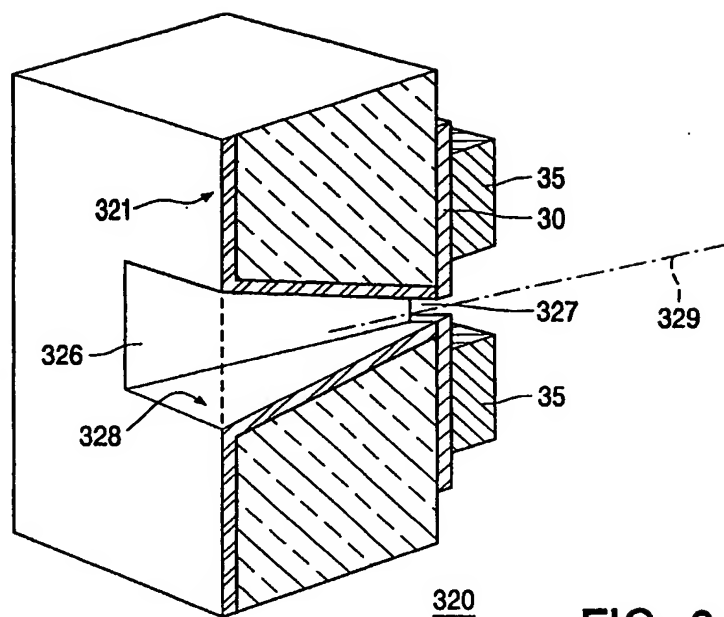


FIG. 6

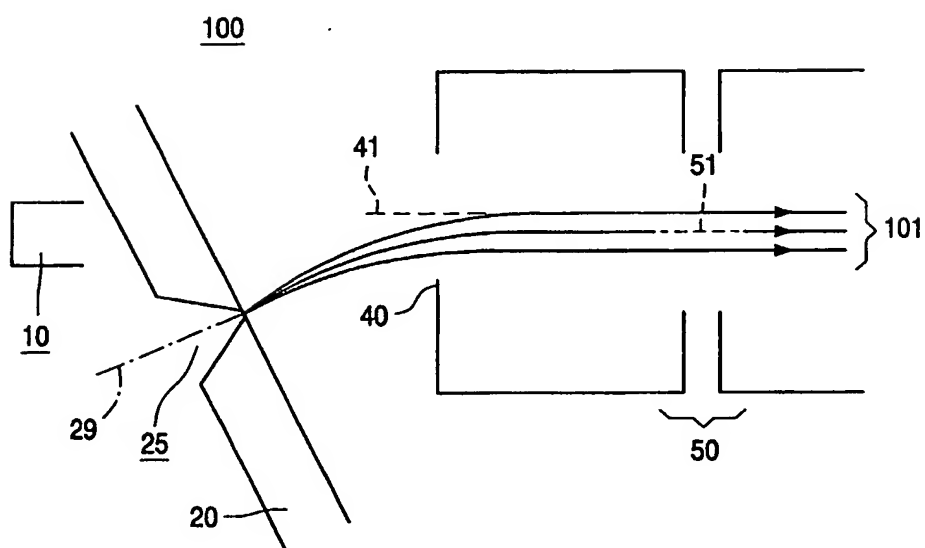


FIG. 7

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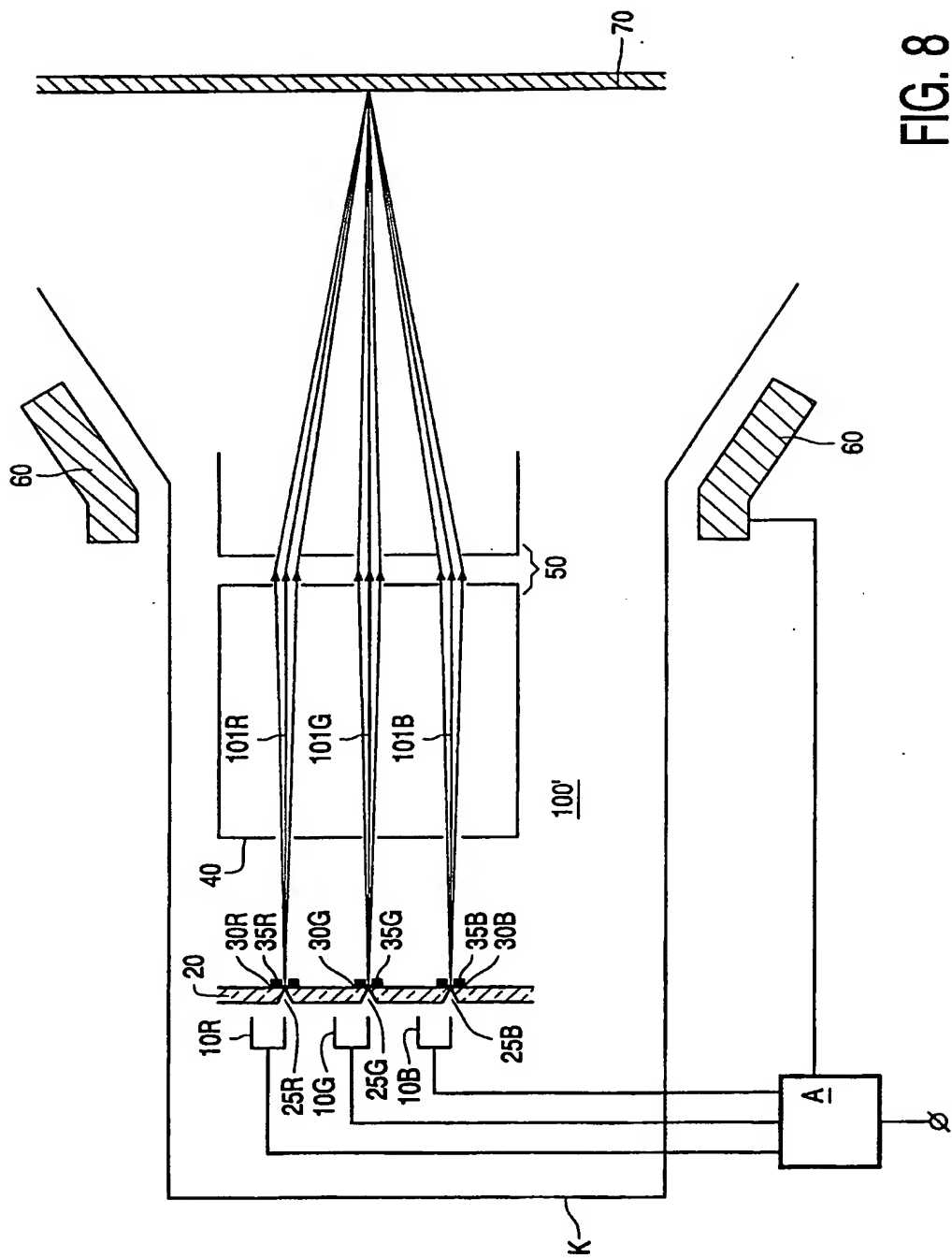


FIG. 8